NASA TECHNICAL TRANSLATION NASA TT F-16,019

ESTIMATING THE EFFECTIVENESS OF HUMAN WORKING CAPACITY UNDER SPACEFLIGHT CONDITIONS

G. T. Beregovoy, N. V. Krylova, I. B. Solov'yeva
and G. P. Shibanov

(NASA-TT-F-16019) ESTIMATING THE EFFECTIVENESS OF HUMAN WORKING CAPACITY UNDER SPACEFLIGHT CONDITIONS (Scientific Translation Service) 16 p HC $3.25

N75-11670

Unclas
G3/53 02849

Translation of "Ob otsenke effektivnosti raboty cheloveka v usloviyakh kosmicheskogo poleta", Voprosy Psikhologii, No. 4, July-August, 1974, pp. 3-9.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D. C. 20546 NOVEMBER 1974

STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TT F-16,019		

4. Title and Subtitle
ESTIMATING THE EFFECTIVENESS OF HUMAN WORKING CAPACITY UNDER SPACEFLIGHT CONDITIONS

5. Report Date
November, 1974

6. Performing Organization Code

7. Author(s)
G. T. Beregovoy, N. V. Krylova, I. B. Solov'yeva and G. P. Shibanov

8. Performing Organization Report No.

10. Work Unit No.

9. Performing Organization Name and Address
SCITRAN
Box 5456
Santa Barbara, CA 93108

11. Contract or Grant No.
NASw-2483

13. Type of Report and Period Covered
Translation

12. Sponsoring Agency Name and Address
National Aeronautics and Space Administration
Washington, D.C. 20546

14. Sponsoring Agency Code

15. Supplementary Notes
Translation of "Ob otsenke effektivnosti raboty cheloveka v usloviyakh kosmicheskogo poleta", Voprosy Psikhologii, No. 4, July-August, 1974, pp. 3-9.

16. Abstract A theoretical approach to the evaluation of a cosmonaut's psychological reserves and psychophysiological functioning in the space man-machine system is outlined. Due to the greater independence of the man-machine system in space, the cosmonaut must be capable of performing as an observer, operator, repairman and as a working reserve on the spacecraft. The ideal function of the cosmonaut in the latter three roles is described in terms of four basic steps used in human factors engineering: information search, situation evaluation, decision-making, and decision implementation. An extreme situation or accident is the best background for evaluating psychological preparedness; both physical and emotional stress situations are simulated for this purpose, e.g., parachute jumping, "escaping submarines by means of torpedo tubes", etc. Correlation of "function quality indices" with "psychophysiological indices" will permit prediction of the functional state and emotional behavior of the cosmonaut in space.

17. Key Words (Selected by Author(s))	18. Distribution Statement
	Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	14	

PRECEDING PAGE BLANK NOT FILMED

ESTIMATING THE EFFECTIVENESS OF HUMAN WORKING CAPACITY UNDER SPACEFLIGHT CONDITIONS

G. T. Beregovoy, N. V. Krylova, I. B. Solov'yeva
and G. P. Shibanov

/3*

Four basic stages can be identified in the conquest of space. In the first stage, the problem of creating technical devices capable of overcoming the terrestrial gravitational field was solved. At this stage, the primary role was played by a combination of the technical sciences.

As soon as this problem was solved, the realistic possibility of studying the existence of living organisms under conditions of spaceflight appeared. Therefore, the second stage in the conquest of space is characterized by extensive involvement of a combination of the medical and biological sciences.

A logical continuation of the second stage was the stage of manned spaceflight using automatically controlled spacecraft. The flights of YU. Gagarin and G. Titov were the first manned spaceflights carried out aboard automatically controlled spacecraft. This stage was necessary, since at that time the capacities of the human operator under spaceflight conditions had not yet been investigated. The experience of a number of the first flights showed man cannot only live, but can also successfully work in space.

* Numbers in margin indicate pagination in original foreign text.

The space walk of A. Leonov in open space and G. Beregov's manual control of the "Soyuz-3" spacecraft heralded the beginning of the third stage in the active functioning of man aboard spacecraft. If the development of aircraft control systems is a gradual transition from manual control to automatic control, systems of controlling spacecraft have the opposite developmental trend — from fully automatic flight to the modern maneuverable spacecraft with manual control [1].

The prospects of mastering space require a study of human capacities to accomplish any particular types of activity, his "psychological reserves", and the effect of spaceflight factors on psychological functions, processes, and states. During this process, the sciences that study the conscious, goal-directed activity of man begin to play the most important role (the 4th stage), and the primary role among these sciences is played by psychology [2].

Today, thanks to flights of Soviet and American astronauts, it has become obvious that man is capable of solving many problems under the conditions of spaceflight. One can discuss the activity of the cosmonaut as a specific form of human activity, under /4 unusual and complex conditions, and requiring a high level of activity: increased readiness to react to suddenly arising, undetermined situations, a capacity to endure g-forces, weightlessness and isolation, mastery of a certain system of knowledge, skills, and capacities, and finally, a high degree of motivation and goal directedness of the cosmonaut's personality [3], [5], [6], [7], [8], [9].

The unique aspect of the cosmonaut's activity is determined by the fact that the "cosmonaut-spacecraft" system is more autonomous than any other "man-machine" system. Due to this, the cosmonaut should accomplish the functions of observer, operator, repairman, and ergative system reserve. This leads to increased requirements for shifting from actions of one type to actions of another type, and also for the capacity to combine actions when necessary.

The multiplicity of functions of the cosmonaut and the necessity of transferring from one type of activity to another complicate the evaluation of effectiveness and control of the dynamics of cosmonaut working capacity. The transfer from observation of operation of automatic systems to manual control, for example, requires a high level of preparation and working capacity. In the meantime, human working capacity can be decreased under the effect of spaceflight factors. Therefore, it becomes necessary to have both special training of the cosmonaut with respect to switching and combining activities, and to develop methods of estimating the quality of activity accomplished and the dynamics of working capacity.

In estimating the quality of human activity under conditions of spaceflight, it is expedient to proceed from concepts on the structure of activity that have developed in engineering psychology, according to which its components (phases) are the following:

- search, perception, and decoding of information;
- estimating the situation according to the totality of isolated signals (signs);
- formulating the conceptual model and making the decision;
- practical realization of the decision taken.

As applied to the specific types of human activity carried out in the "man-machine" system of the function of operator, repairman or ergative reserve, each of the above-mentioned phases has its own particular aspects.

For a man carrying out the functions of operator, the specific aspects consist in the fact that the predominant component in human activity is observing the behavior of the controlled object (for example, attitude in space, velocity, temperature, pressure, dynamic characteristics of the most important components that determine the quality of the control, etc.), with the use of different sources of information, (visual, acoustic, tactile). This requires the human operator rapidly to switch from some types of information concepts to others, and requires increased attention, which in most cases leads to a limiting load on the operator's sensory organs and to rapid fatigue.

At the second phase in the activity of the human operator, analysis of the factual information obtained from the controlled object for processing and its comparison with the information standard for the stage of assigned flight regime of the object, or the technological regime of the controlled process, predominates. At this phase, the following actions are most difficult to realize:

- timely and correct extraction from memory of the necessary information, characterizing the "ideal" control process; /5
- estimating the situation that has developed based on a comparison of the totality of signs with the corresponding region of their limitations (this requires high professional training of operators).

A complex estimate of the effectiveness of the human operator activity in the first and second phases can be carried out according to the numerical values of certain quality indices for the tracking operation — for example, the mean square deviation of the tracking error, the number of maximally permissible deviations in tracking parameters over a given interval of time, dispersion and mathematical expectation of tracking errors, etc.

In the third phase, the specificity of operator activity is expressed in the necessity of deciding on the method of control which can be expediently realized in the situation that has developed, in the presence of false or inadequate relevant information about the controlled object (process). At this stage, the effectiveness of the operator's work can be estimated according to the time of formulating the earlier unknown algorithm necessary for control, or according to the time required to choose the required sequence of controlling actions, based on one or more particular algorithms from a number of known ones.

The specifics of the fourth phase consist in the fact that this phase is a total phase with respect to the preceding activity, and the errors that have been made in formulating the controlled actions can nullify all the work of the operator that has been carried out in the preceding phases of activity. This characteristic of the fourth phase should be taken into account when simulating the activity of the human operator under stress conditions by assigning corresponding "weights", and proportional "costs" of each operator error made during this phase to the numerical quality criteria of activity, and with respect to the required psychological level of training, with a permissible value of the probability of erroneous or untimely formation of the controlling operation.

In the activity of the repairman in servicing the technical equipment of the "man-machine" system, the first phase consists of information on the condition of the controlled system, which is gathered from the output devices (signals, indicators, digital print-out devices), of the control-checking equipment. In this phase, the human role is reduced to putting the facts together; "the system is capable of operation", or "the system has lost the capacity to operate". The search for the primary information characterizing the working capacity of the checked system and the decoding of this information, as a rule, is carried out automatically.

The second phase in the activity of the repairman is only realized in the case of deducing the facts; "the system has lost its functioning capacity". In this phase, there is either an analysis of additional information that makes it possible to establish the reason for the loss of functioning capacity of the checked system (or the location of a malfunction), or (in the presence of facilities of automatic diagnosis of malfunction), an analysis is made of the probable causes and locations of malfunctions indicated by the automatic device, and of the information characterizing functioning capacity of the automatic means of control and diagnosis.

In the third phase, the repairman formulates the problem of preventive maintenance or repair of the system, determines the order of restoring functioning capacity, compares the time necessary for preventive maintenance or repair with the time he has at his disposal, and determines the necessary make-up of materials, spare parts (modules, assemblies, blocks), instruments, accessories, and instruments. In a given case, decision making can be formulated as a task of multiparameter optimization whose solution is difficult even in the absence of stress conditions.

/6

The activity of the repairman in the fourth phase pertains to preparing the means of repair (instrument, accessories, instruments) for carrying out the plan of preventive maintenance (repair), formulated in the process of making the decision, and the subsequent check of functioning capacity of the repaired system.

If the reason for the loss of functioning capacity of the checked system has been established correctly, and if the plan of preventive maintenance or repair has been correctly realized, and final check of the system will show that it is capable of functioning. If as the result of the check it has been established that the system subjected to preventive maintenance or repair is not capable of functioning, the repairman should once again return to the first phase of activity. This situation enables one to conclude that, in simulating the activity of the repairman under stress conditions, the integral estimate of his working effectiveness should expediently be carried out according to a criterion which would take into account not only the complexity of repair operations and the total time of restoring the lost functioning capacity of the system, but also the number of transitions from the fourth to the first phase, inasmuch as it characterizes the quality of carrying out preventive maintenance and repair operations on the whole.

The specifics of human activity carried out in the "man-machine" system, with man playing the role of the ergative reserve, pertain to the following. In the first phase he receives and decodes information on the condition of automatic systems that perform the algorithm of automatic guidance or control, while in the second phase he compares the decoded information with information accepted as a standard for the given conditions and regimes of operation. If the results of the comparison prove to be within permissible limits, the man carrying out the functions of ergative reserve returns with an assigned period to the first phase of his activity. In this case, his activity during normal operating regimes of the automatic equipment becomes cyclic and pertains to a sequential accomplishment of the first and second phases.

When the results of comparison exceed the permissible limits in the second phase, an analysis of the causes of this outcome is additionally made. The results of analysis are then used in the third phase for making a decision as to which of the automatic systems should be cut off, and for formulating the conceptual model of human activity with respect to the switch from automatic to manual guidance or control regime.

In the fourth phase, practical realization of reserve control and guidance algorithms is carried out, and the man, having carried out functions of the ergative reserve prior to this, is actually changed into an operator whose activity specifics have been described above.

It should be noted that in the manned spacecraft that have a high degree of autonomy, the forms of activity enumerated are not limited. A characteristic of the cosmonaut's work is the fact that the same person (crew member), depending on the situation that has specifically developed, must carry out functions of operator and repairman and ergative reserve. Naturally, the man who is a branch of such "man-machine" systems, should fulfill the requirement of "universality". The estimate of suitability of a man for working in such a system should pertain to quality criteria for all three types of activity, and the most complex algorithms inherent to each of the above-mentioned types of activity whould be chosen as a background.

According to each of the described types of activity and their combinations that follow from the requirements of practice individi- /7
dually, the degree of human occupational suitability should be estimated according to criteria that take into account his psychophysiological characteristics (rapidity of reaction, memory characteristics, accuracy of sensory-motor coordination, etc.), as well as his capacity to make correct decisions in complex (emergency) situations. Here, it is vital to take the fact into account that man's working effectiveness basically depends on his psychological preparedness to act in the emergency situation.

Estimating the quality of human psychological preparedness for activity under emergency conditions is expediently carried out by using three types of emergency situations that significantly differ from each other with respect to their specifics and force of emotional impact:

- situations studied earlier but which have not appeared suddenly;
- situations not studied before, not thought of before, and that have occurred as the result of the sudden appearance of combinations of breakdowns, not previously encountered;
- situations in which a threat to the health or life of the man (the crew) directly appears.

When developing the criteria of such an estimate, it is vital to take into account the timeliness of discovering the reasons leading to the emergency situation, timeliness and correctness of making a decision to assign the given emergency situation to one of the three indicated types, with the goal of formulating a conceptual model of further activity, including an estimate of the situation (creating the environmental model), and developing a plan of activity, and finally, the correctness of predicting the development of events and the effectiveness of actions aimed at localizing or eliminating the emergency situation.

Simulation of the indicated emergency situations is expediently carried out both on the training apparatus linked with a digital analog simulator complex and an actual system for depicting information that is supplied with false emergency signals, or that breaks down without appropriate signals, and directly by means of creating physical conditions that are near actual stress conditions. This is done by creating an emotionally tense background — such as a situation which exists, for example, during flights aboard different aircraft, when abandoning submarines through torpedo tubes, in jumping with parachutes, etc.

Estimating the quality of human professional training and activity under conditions of both individual stress factors and combinations of them can be carried out both under laboratory conditions and conditions that approach realistic ones.

In the former case, physical simulations of conditions under which rapid human fatigue ensues or where there is a severe deficit of time, a surplus or deficit of information, etc. are used.

/8

In the latter case, the basic simulation task can consist of creating an adequate emotional stress that appears in connection with exposure to danger, upon increasing responsibility, a time deficit, a load on attention, etc. The quality of human work in this case is estimated according to timeliness and accuracy of conscious actions [4].

It should be noted that estimating the quality of human occupational preparation during the action of various stress factors is done by taking into account the psychophysiological indices of his functional conditions, since complete recording and timely analysis of such indices make it possible to draw an objective conclusion as to expended efforts and inner reserves.

Correlation of the activity quality and the psychophysiological indices makes it possible to predict human functional condition and occupational activity, as well as behavior under emotionally tense conditions of work.

The authors consider that the implementation of the investigations noted in this article can lead to the creation of a system for operationally estimating the condition and for predicting the quality of human activity under stress conditions.

Conducting the corresponding investigations and creating such a system are important, complex problems requiring the involvement of specialists of different disciplines, without which a successful solution is unthinkable.

REFERENCES

1. Beregovoy, G. T., V. A. Popov, and V. A. Ponomaranko. Man and Flight Control. "Aviatsiya i kosmonavtika", 1972, p. 10.

2. Gorbov, F. D. Space Psychology, "Kosmicheskaya biologiya i meditsina", (Space Biology and Medicine). Moscow, "Nauka", 1966.

3. Denisov, V. G., V. F. Onischenko. Engineering Psychology in Aviation and Cosmonautics. Moscow. "Mashinostroyeniye", 1972.

4. Inzhenereno-psikhologicheskiye trebovaniya k sisteman upravleniya, (Engineering-Psychological Requirements on Control Systems). Edited by V. P. Zinchenko. Moscow, "VNITE", 1967.

5. Zavalova, N. D., B. F. Lomov, V. A. Ponomarenko. The Principal of the Active Operator and the Distribution of Functions between Man and Machine. "Voprosy psikhologii", Number 3, 1971.

6. Ivanov, Ye., V. Popov, and L. Khachatur'yants. The Working Activity of the Cosmonaut in Weightlessness and Unsupported Space. "Medikobiologicheskiye issledovaniya v nevesomosti". (Medical-Biological Investigations in Weightlessness). Moscow, "Meditsina", 1968.

7. Ivanov, Ye. A., V. A. Popov, L. S. Khachatur'yants, and Ye. V. Khrunov. Chelovek-operator v kosmicheskon polete, (The Human Operator in Spaceflight). Moscow, "Mashinostroyeniye", 1974.

8. Lomov, B. F., Chelovek i tekhnika (Man and Technology). Moscow, "Sovetskoye Radio", 1966.

9. Ponomarenko, V. A., and N. D. Zavalova. Characteristics of Pilot Behavior During a Complication of the Flight Situation. "Voprosy psikhologii", Number 5, 1970.

Translated for National Aeronautics and Space Administration under contract No. NASw 2483, by SCITRAN, P. O. Box 5456, Santa Barbara, California, 93108.